Active Crustal Strain Rates in Western Wyoming and Surrounding Areas: Very Slow But Not Zero

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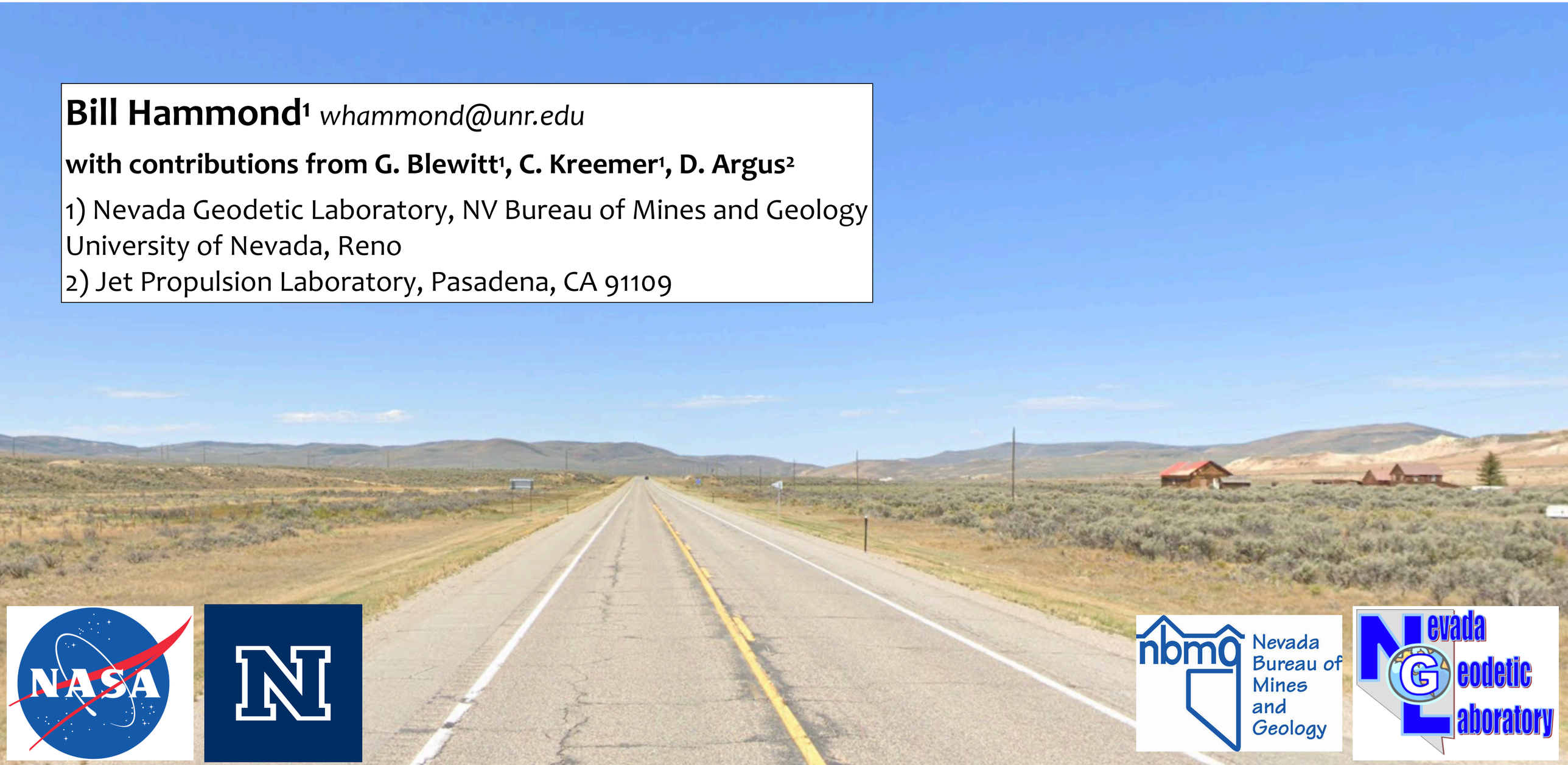

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"Where is the eastern limit of active crustal deformation associated with the western North America tectonic plate boundary?"

NASA

N

nbmg Nevada Bureau of Mines and Geology

Nevada Geodetic Laboratory

Wyoming: The Tectonic Framework

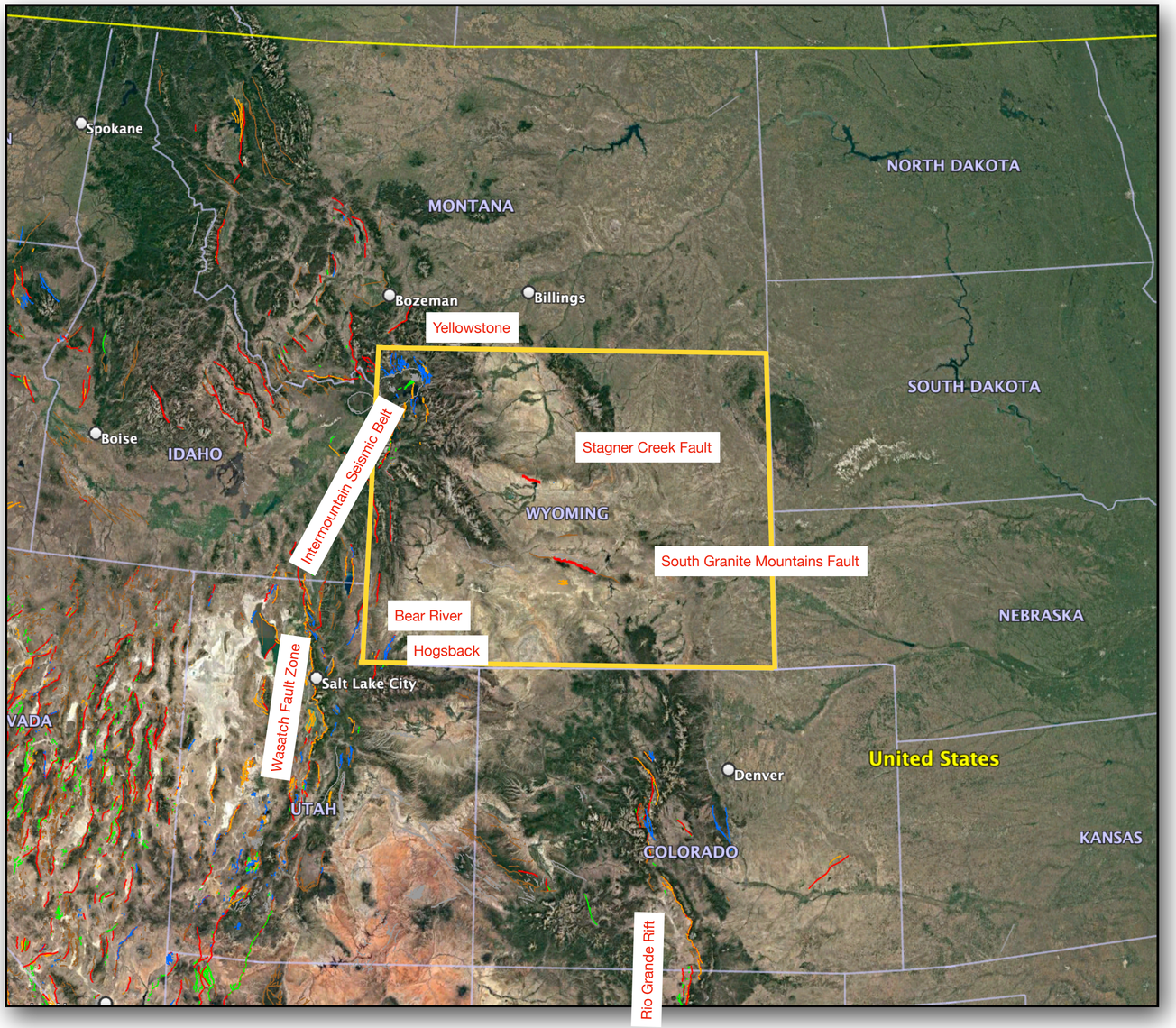
Western Wyoming:

The state is mostly east of main band of higher rates of interseismic strain accumulation along the **Wasatch Fault Zone**, **Intermountain Seismic Belt** and **Yellowstone**.

Some mapped faults 100 km east of the belt: Bear River, Hogsback in the southwest corner of WY

Some are 300 km east of the belt: Stagner Creek, South Granite Mountains in central Wyoming

North of the Rio Grande Rift / San Luis Basin, Normal Fault systems in central Colorado



Google Earth map with USGS Quaternary Fault database

The Tectonic Framework

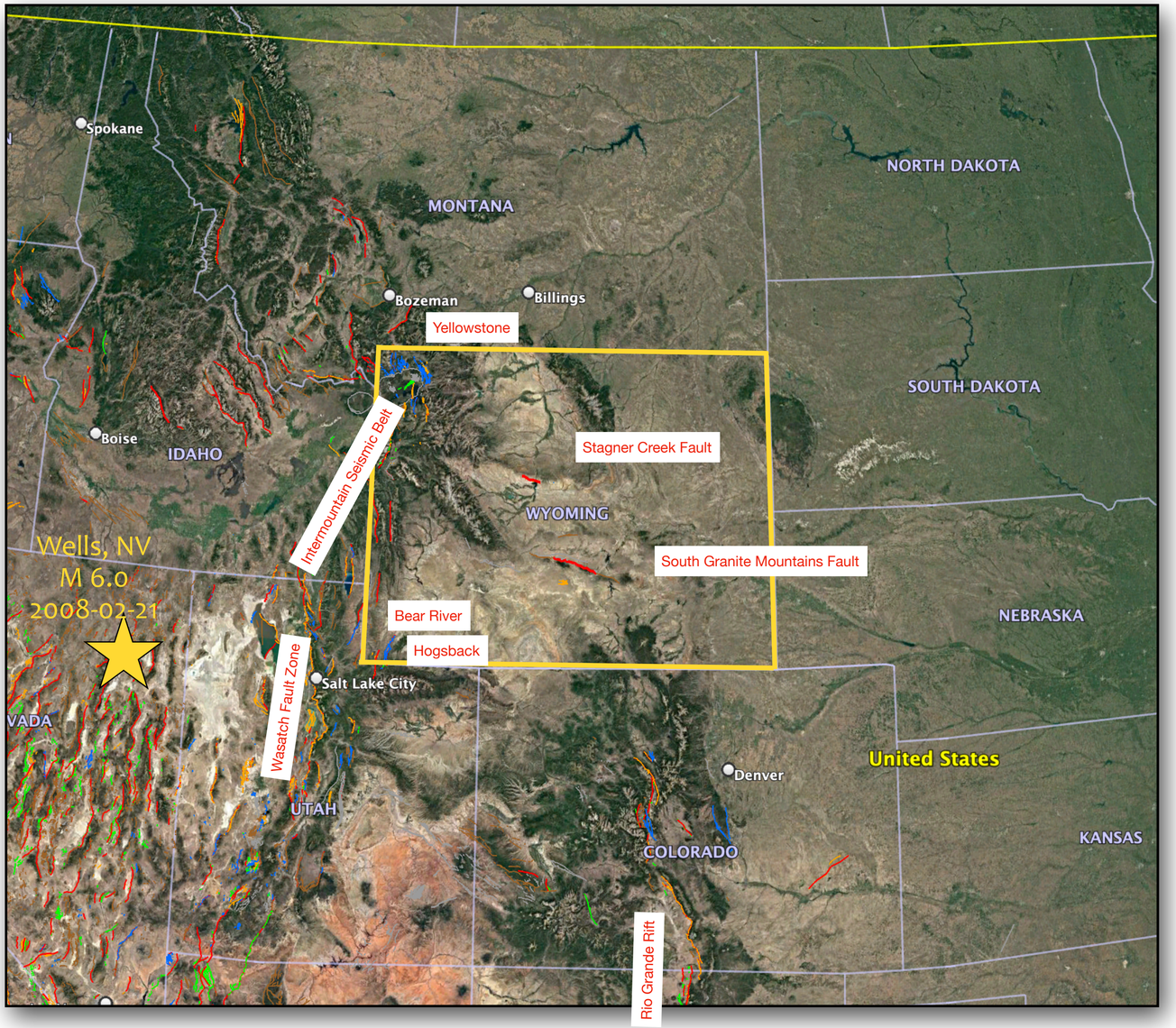
Western Wyoming:

But very low strain rates are sometimes associated with active seismicity and recent faulting

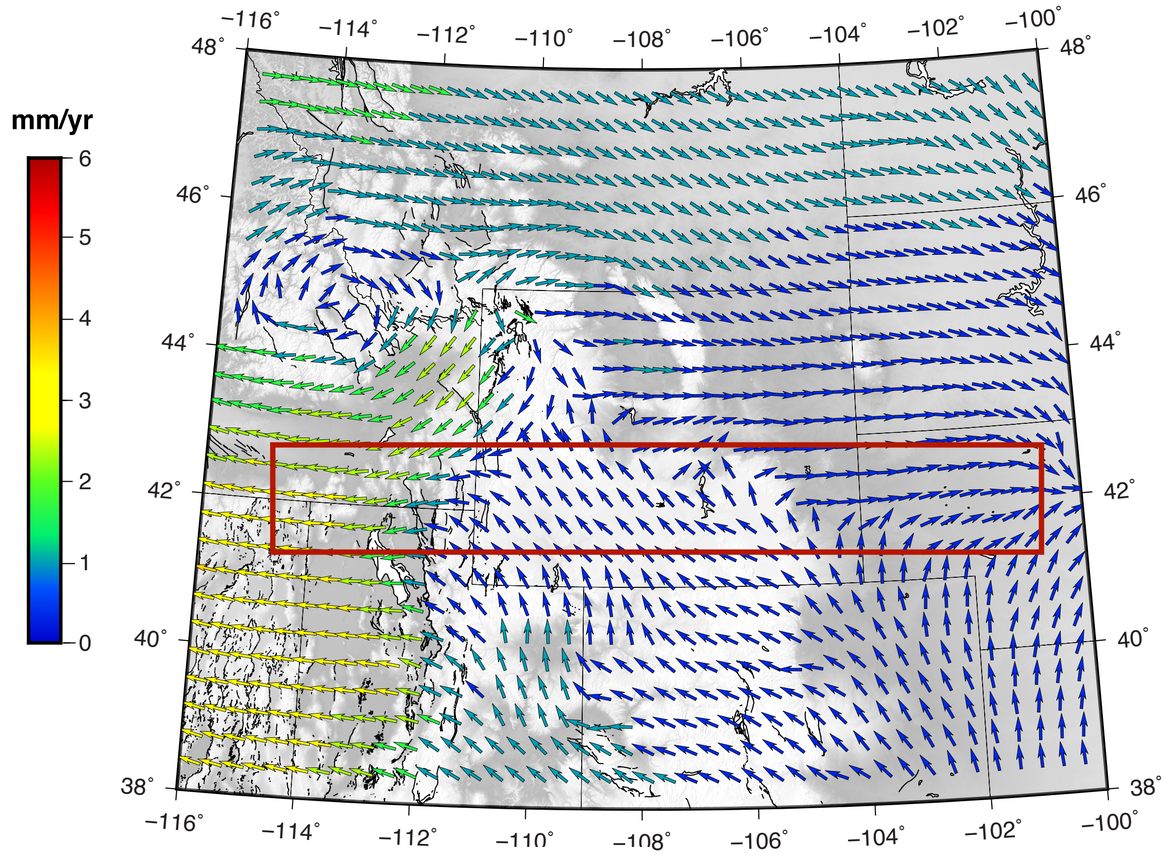
e.g., the Eastern Nevada Basin and Range (<5 10^{-9}/yr) was the location of an M6.0 earthquake in Wells NV in 2008.

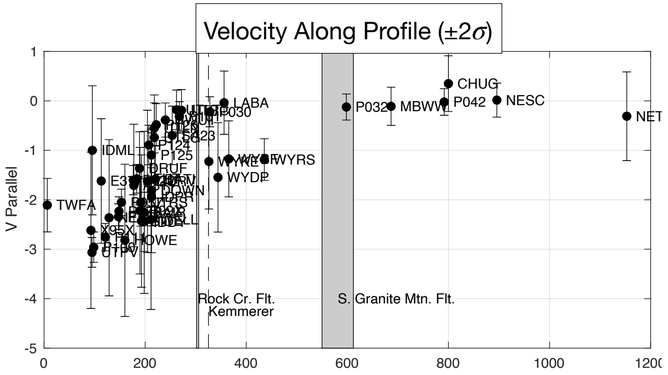
Need to know and assesses fault slip rates, seismic hazard estimation, understand risk from earthquakes.

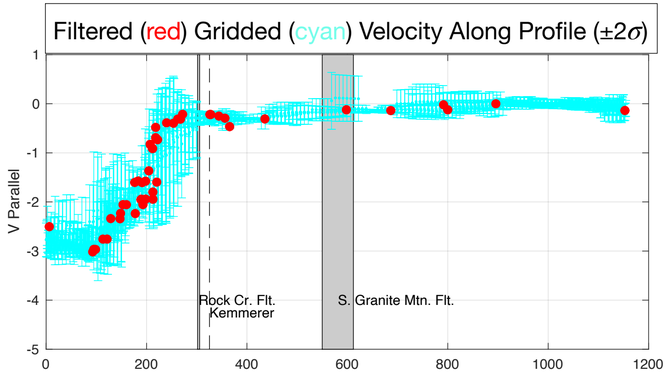
But to do this we will need to look at the strain rate data carefully and compare it to sources of error and signals from other processes.



GPS Velocities Filtered and Imaged







Data:

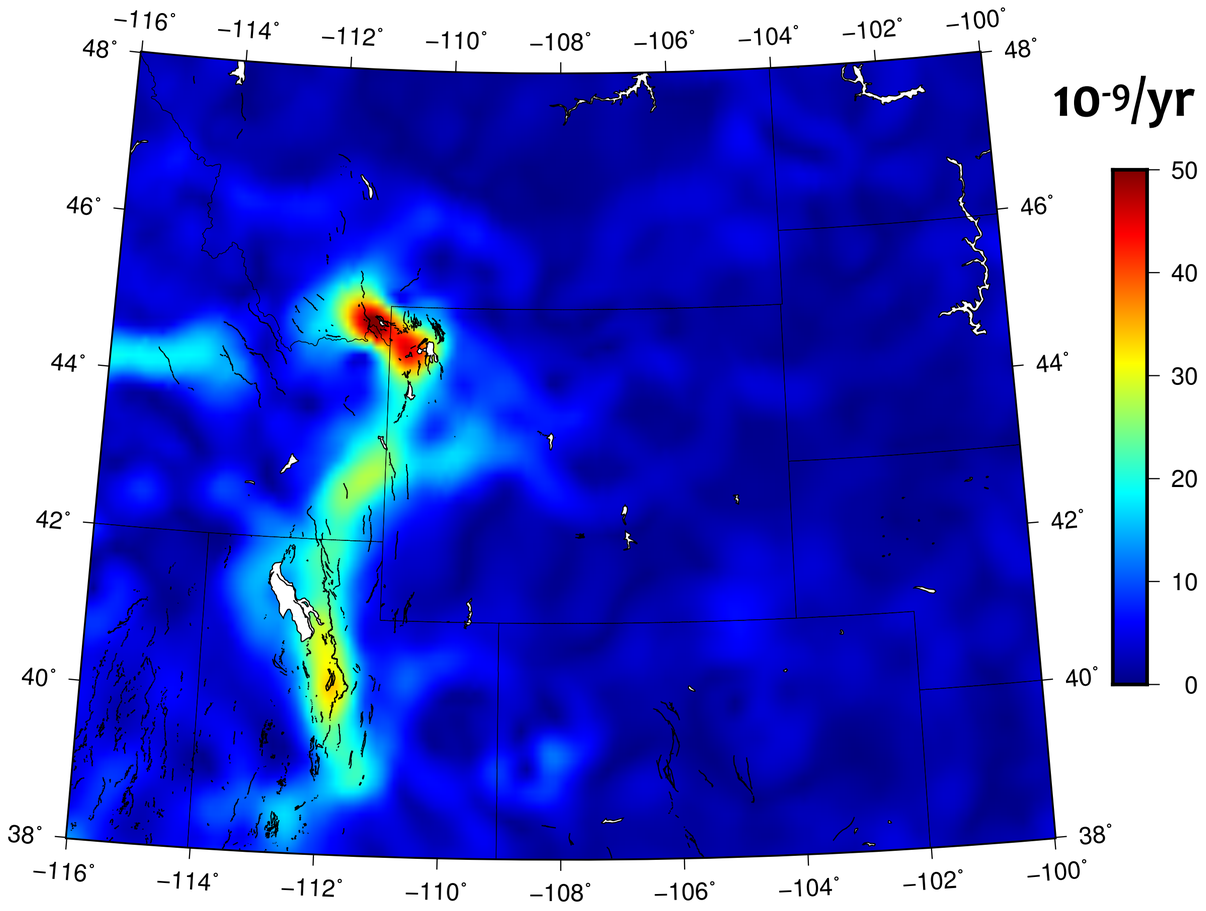
- Nevada Geodetic Lab MIDAS velocity field from continuous GNSS stations in **Wyoming reference frame**
- + Other published campaign velocity fields, and USGS campaigns, align all with MIDAS field.
- Median spatial filter, eliminate outliers, interpolate velocities onto a grid.
- Plot with constant length vectors, color denotes magnitude.
- Highlights details of small velocity gradients

See Domains:

- Transition across Wasatch/Intermountain Seismic Belt/Yellowstone/Eastern Snake River Plain
- Southwest WY moving NW wrt Northeast WY
- Profile shows very low *but not exactly zero* gradient in western half of Wyoming
- About 0.4 mm.yr over hundreds of km

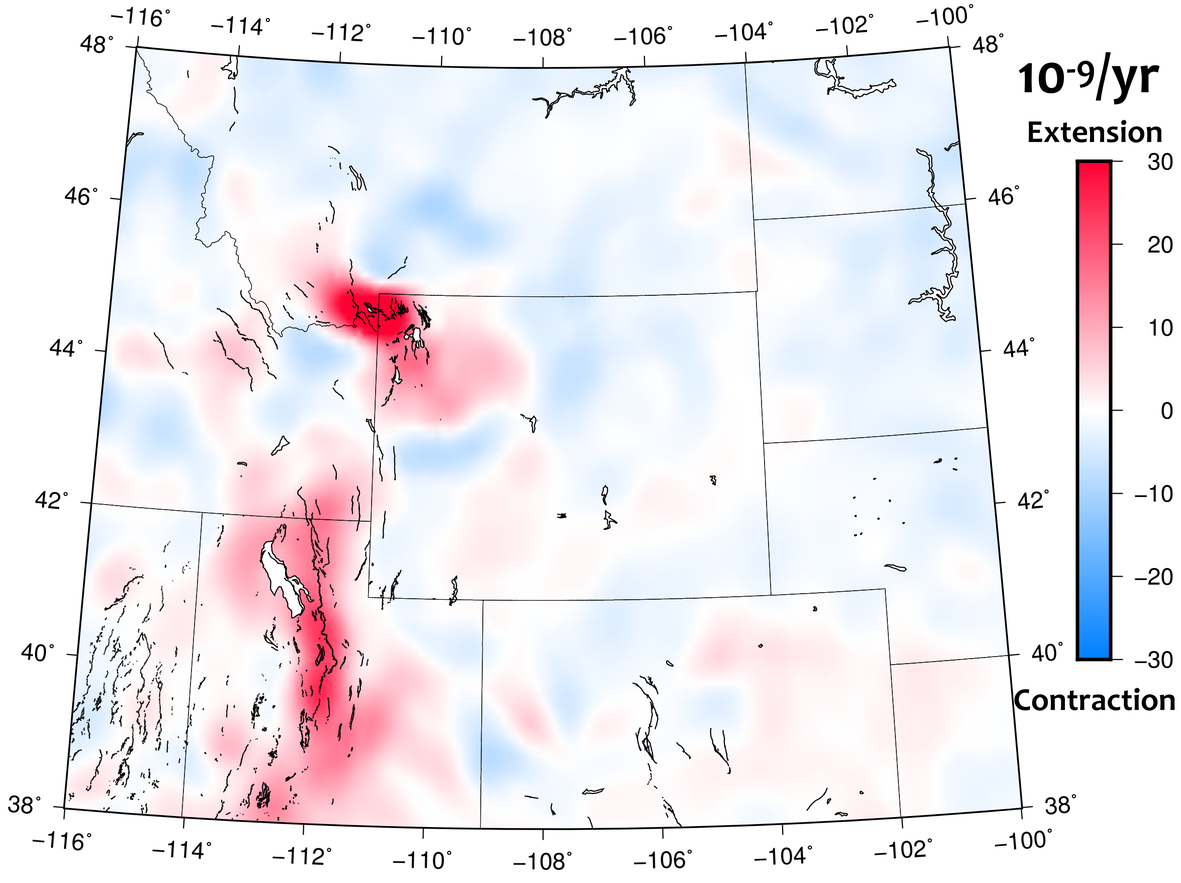
GPS Strain Rates From Imaged Velocities

Shear Strain Rate



Highest strain rates in Wasatch/ISB
Some wormy features in very low strain rate areas
Other kinds of signals plus measurement noise

Dilatational Strain Rate



High rates at Wasatch/ISB/Yellowstone
Zones of dilatation to the east
Clouds of low rate extension/contraction

Strain Rate Domains

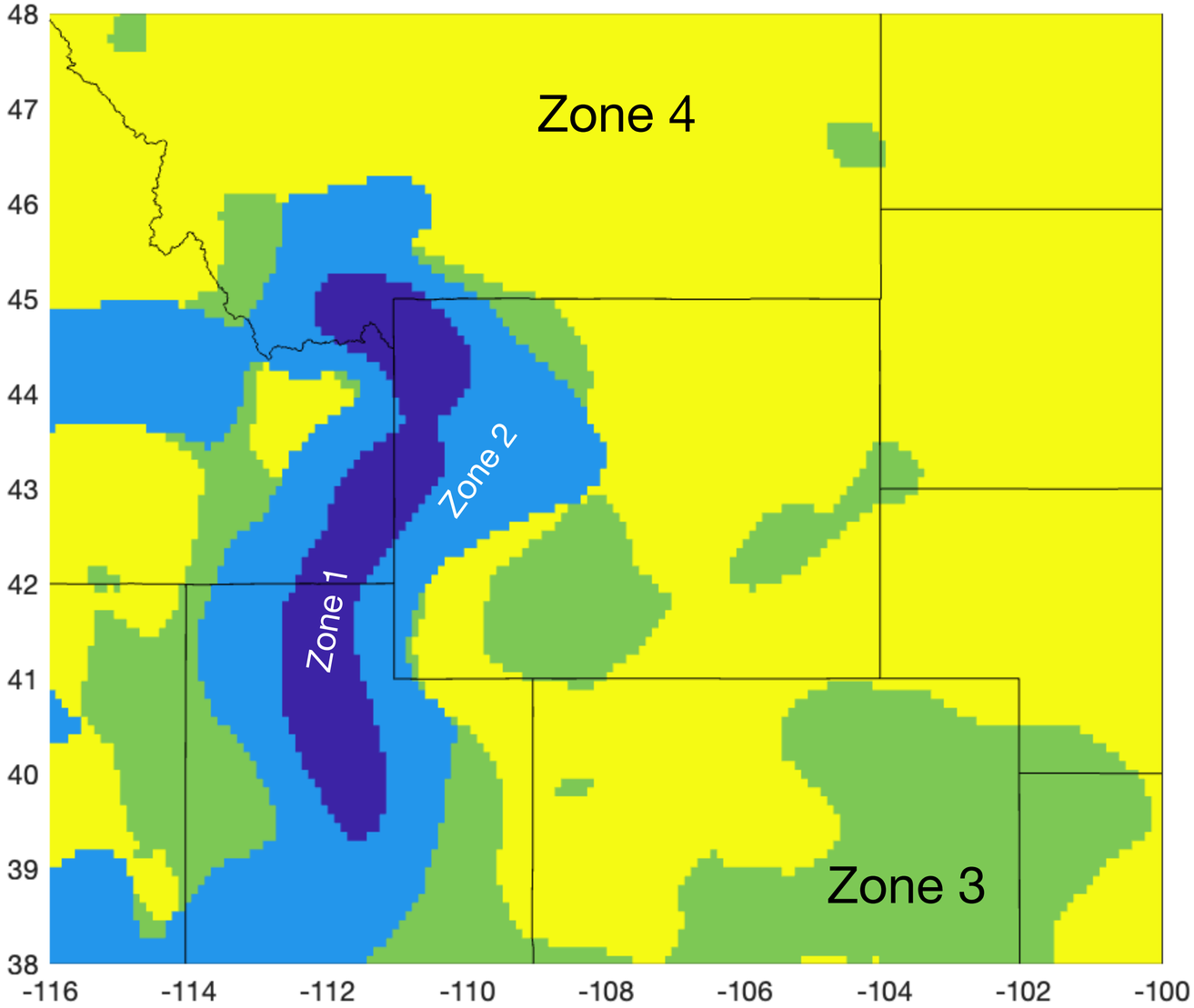
Simplify the field to visualize strain rate domains.

Zone 1 - High strain rates of Wasatch/ISB/ Yellowstone (>15 x 10^{-9}/yr)

Zone 2 - Halo of lower but still elevated strain rates (5 - 15 x 10^{-9}/yr), penetrates 100-300 km east

Zone 3 - All other areas with dilatational strain rate>0 (net extension, hydro signals?)

Zone 4 - All other areas with dilatational strain rate<0 (net contraction, dominated by GIA)



Compare Strain Rate to Crust/Mantle Structure

Western Wyoming:

Clean similarity between the arcuate pattern of higher strain rates and transitions in crust and mantle seismic wave speed.

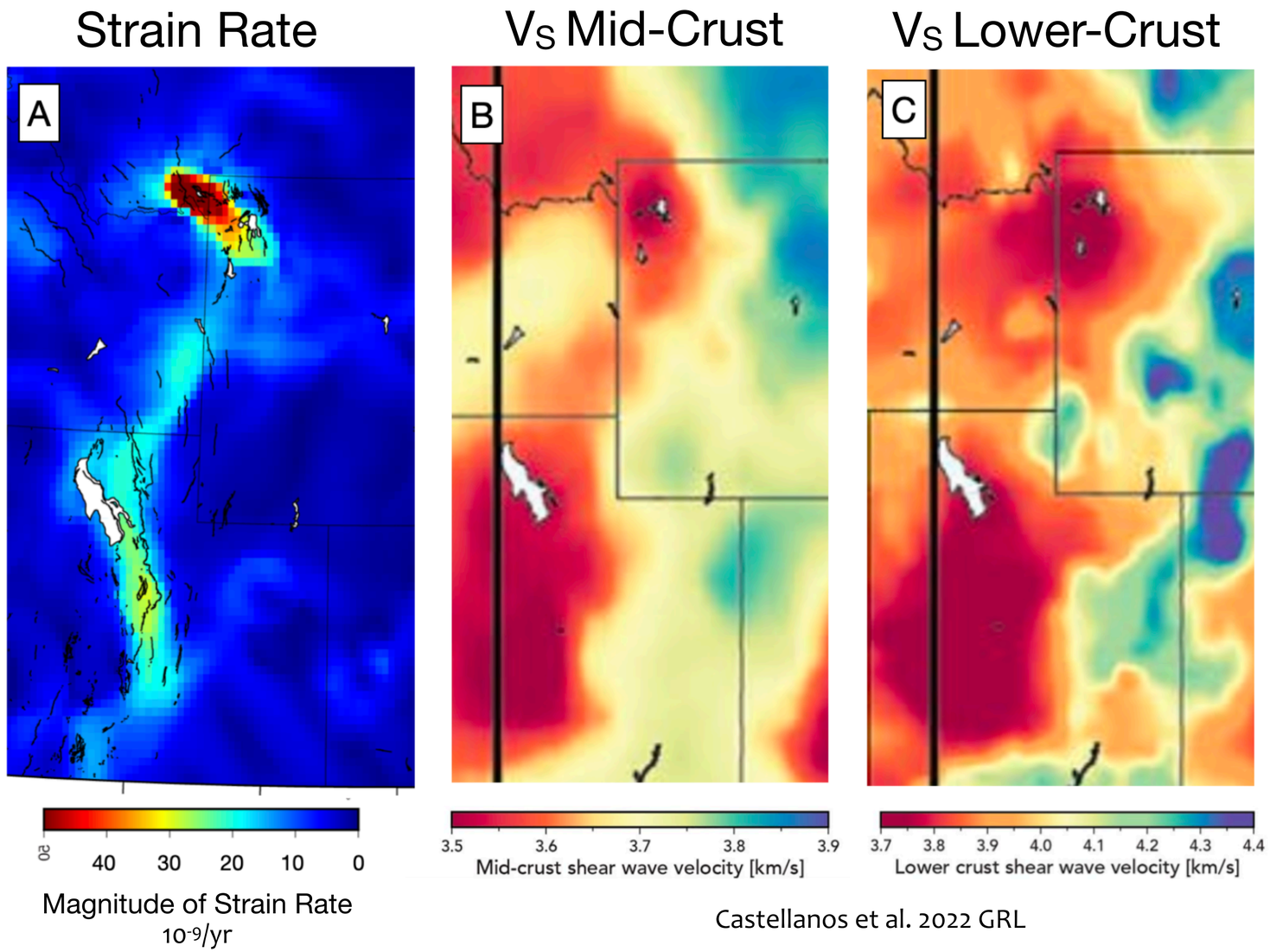
Seismic anomalies also penetrate 100-300 km into western Wyoming

Possibly related to lithospheric strength contrast and ongoing tectonics

While this correlation deserves more scrutiny, it may suggest that high strain rates are a persistent feature

As opposed to a transient from hydro-loading, post earthquake relaxation, or GIA.

Suggest plausibility of significant tectonic deformation penetrating 100-300 km eastward.



Castellanos et al. 2022 GRL

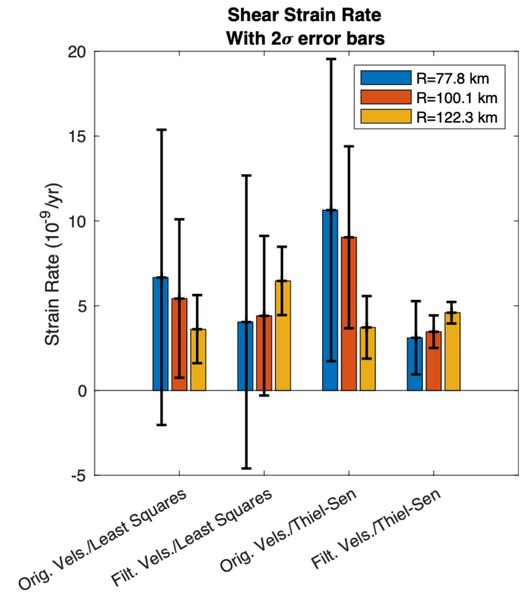
Strain Rates At Specific Locations

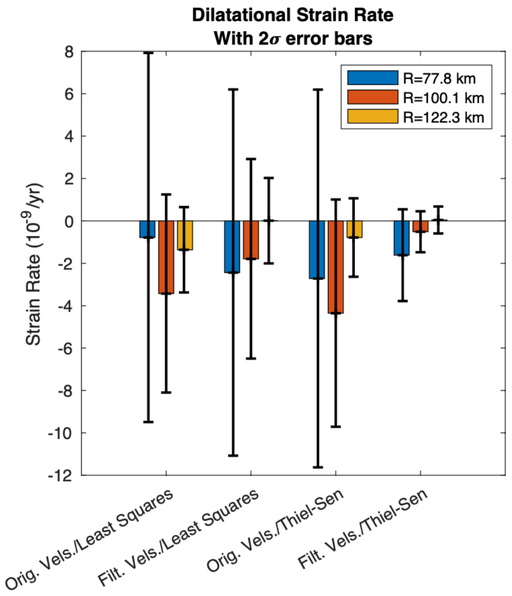
Focus Attention:

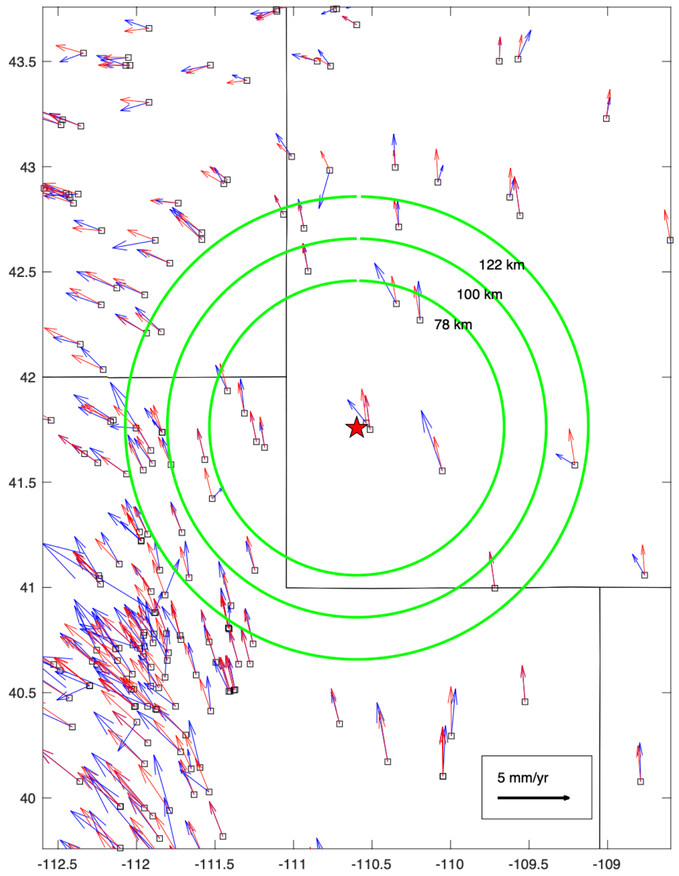
- Estimating tensor strain rate from GPS site data **100 km east of Wasatch/ISB**

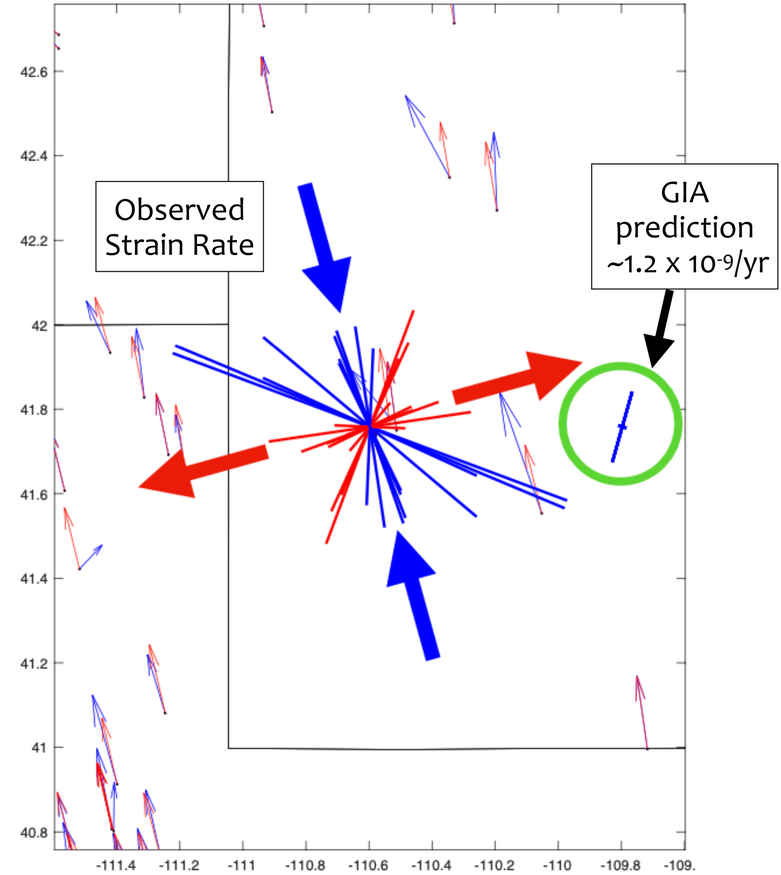
Use:

- Multiple techniques including least squares and robust methods on a sphere.
- Multiple radii *r*= 78, 100, 122 km
- Find **significant shear strain rates** when *r* >100 km or when using robust methods







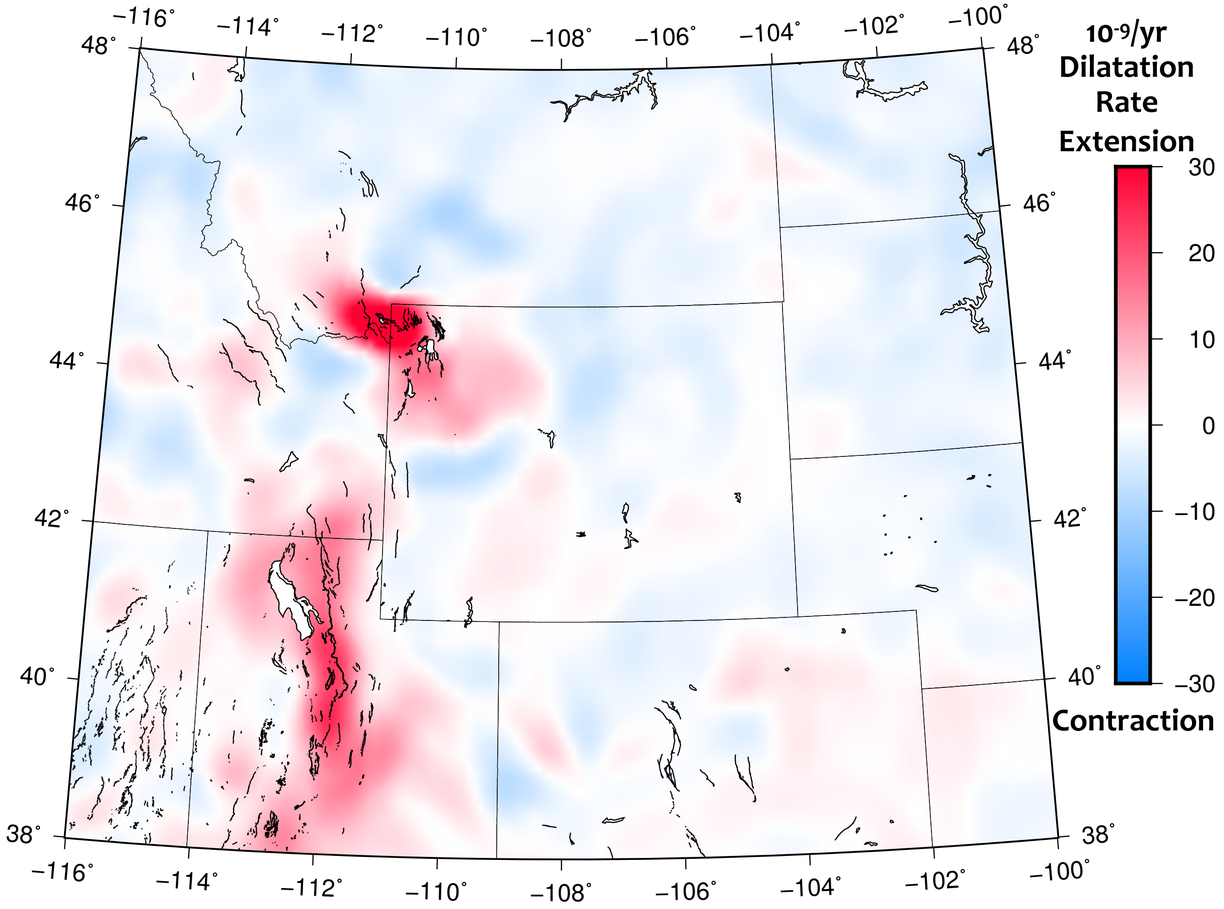


But what about Glacial Isostatic Adjustment?

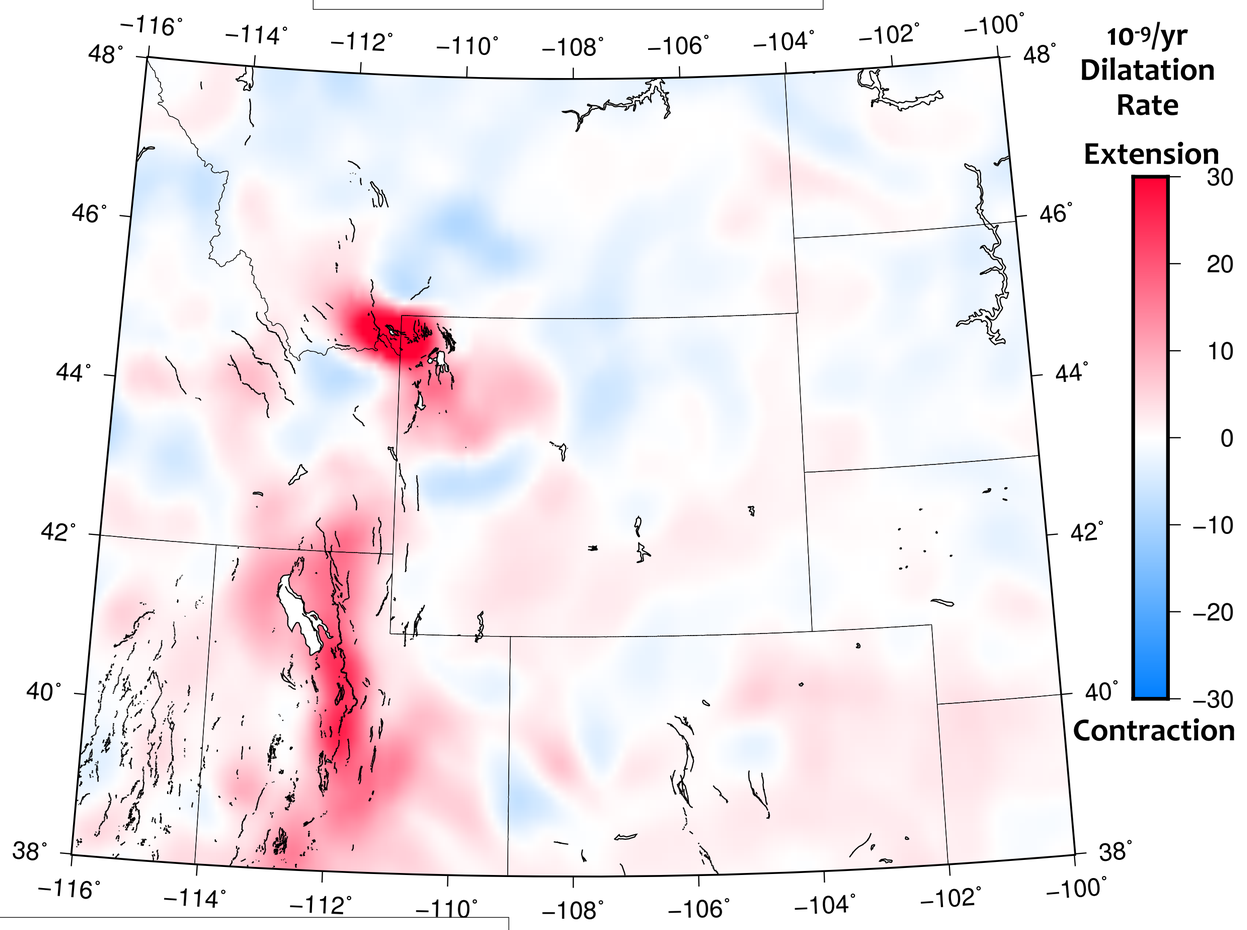
- Expect GIA to contribute small but measurable signals
- Green circle on right shows strain rate expected from GIA model ICE6G (Peltier et al., 2014)
- Differs in rate, azimuth and style from observed strain rate

What About Glacial Isostatic Adjustment?

Dilatational Strain Rate



Dilatational Strain Rate
Corrected for GIA



Very Small Differences.

ICE6G GIA model does not explain:

- low rate and pervasive contraction northeast
- or extension in southern Wyoming and Colorado

So what are these signals?

What About Hydrological Loading?

Can small scale zones of dilatation be explained by hydrological loading?

Drought-related uplift seen in GNSS networks at, e.g., High Plains Aquifer

But what about horizontal motions east of ISB?

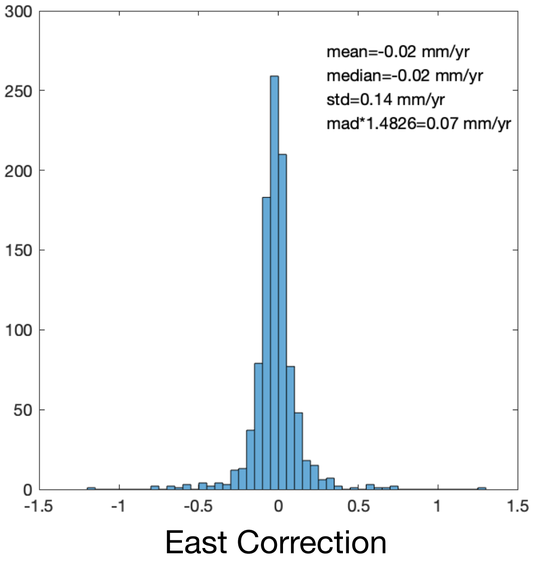
Tested by applying corrections for NTAL, NTOL, GRACE-based MASC loading products (GFZ : Dill and Dobslaw, 2013 JGR).

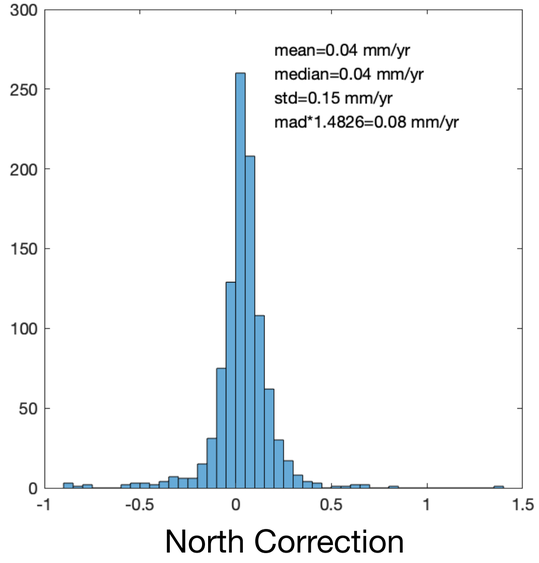
(These corrections are now available on all NGL station pages)

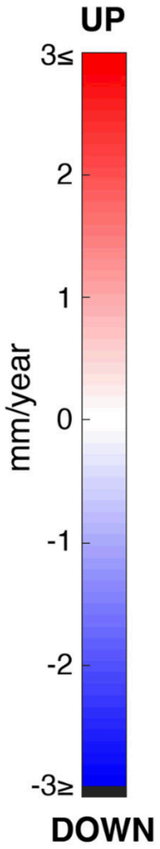
Differences between corrected / uncorrected show:

- Near zero mean
- Standard deviation ~0.1 mm/yr
- Are greater than data uncertainties less than 1% of the time

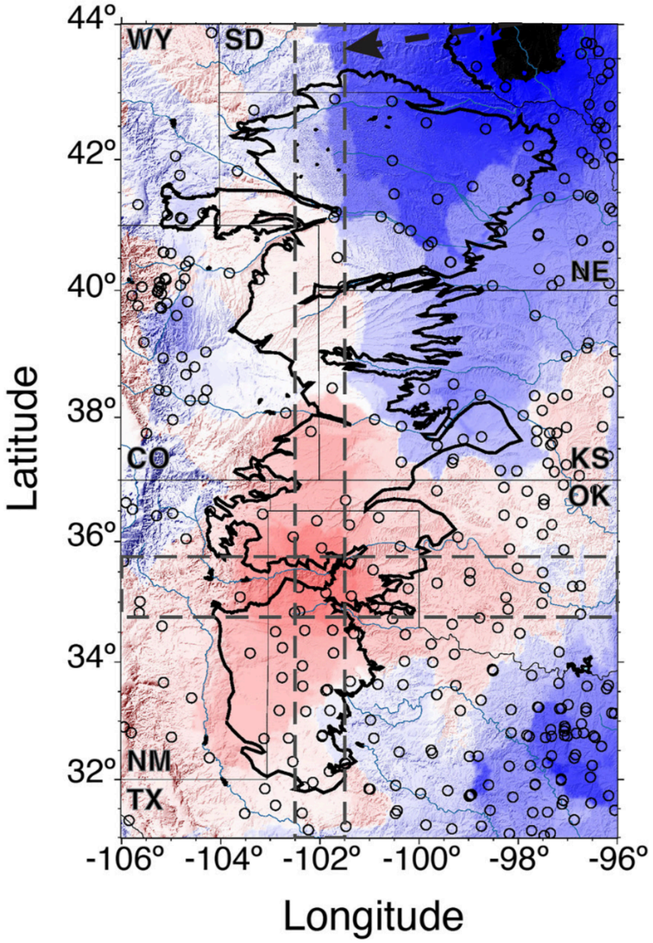
Conclude: probably not hydro-loading, but further analysis is needed.







Southern High Plains Aquifer



Overacker et al., 2022 WRR

Conclusions

- Data from GNSS networks indicate significant active crustal strain rates in western Wyoming
- The area with strain rates >5 nanostrains/year extends 100-300 km east of the Wasatch Fault Zone, Intermountain Seismic Belt, and Yellowstone
- These strain rates are not well explained by predictions of glacial isostatic adjustment or hydrological loading available in current models
- Distribution of strain rates are similar to seismic velocity patterns in crust and upper mantle, suggesting they are persistent and contribute to seismic hazards